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ABSTRACT

The three reports in this collection are based on research reviews and original research from both published and unpublished sources, covering the years 1986 through 1990, and they reflect the broad array of factors that determine the effectiveness of technology-based instruction. The first report discusses research studying the effects of microcomputers on student achievement. Such studies compared computer-assisted instruction with more traditional instructional methods, and related student achievement to software design, learner characteristics, and implementation decisions. Research demonstrating the power of microcomputers and other educational technologies to motivate students and to improve their attitudes about learning and themselves is discussed in the second report. Finally, the effects of microcomputers on social interaction and relationships within the classroom are examined. Each study included in these reports is cited in the bibliography. (61 references) (DB)

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Northwest
Suite 901
Washington, D.C.
20036

Telephone
202/452-1600

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About the Authors:

This research review was compiled for the SPA by Ellen Bialo and Jay Sivin of Interactive Educational Systems Design, Inc.

Ellen Bialo *holds undergraduate and masters degrees in mathematics and education, and is currently completing a Ph.D. in Educational Psychology at Teachers College, Columbia University. Ms. Bialo has trained educators throughout the United States at all levels (from teachers to superintendents) to effectively evaluate and select educational software. After ten years in the classroom, she conducted research on characteristics and design trends of educational software and on the integration of technology by educators. Recently she collaborated on a report for the Congressional Office of Technology Assessment which analyzed the scope and quality of software. Ms. Bialo is currently president of Interactive Educational Systems Design, Inc.*

Jay Sivin *holds an Ed.D. in Technology in Education from Teachers College, Columbia University in New York. Dr. Sivin served as Director of Microcourseware Evaluation at the EPIE Institute, where he authored EPIE's comprehensive software evaluation training manual. He has collaborated on software-related articles for Psychology Today, Classroom Computer Learning, and Consumer Reports. He is a former teacher of remedial reading, English, and journalism, and has served on the faculty of New York University. Dr. Sivin is currently vice president of Interactive Educational Systems Design, Inc.*

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Report on the Effectiveness of Microcomputers in Schools: Overview

When the computer first became available to our nation's schools, some saw it as a magic cure for all that ails our educational system. However, our understanding of educational technology is becoming more sophisticated. Happily, a growing body of research confirms what many teachers and students already know -- that under the right circumstances, using technology as a learning tool can make an important difference.

Evidence suggests that such positive effects are dependent on a combination of important conditions, including: the subject area, characteristics of the student population, the teacher's role, how students are grouped, the design of the software, and the level of access to technology.

This information packet presents three reports on some of the "good news" from recent educational technology research:

* Effects on Student Achievement
* Effects on Student Motivation and Attitudes
* Effects on Social Interaction in the Learning Environment

Also included in the packet is a bibliography of the research cited.

The enclosed reports are based on research reviews and original research, from both published and unpublished sources, covering the years 1986 through 1990. The research varies in methodology. Some studies compare the use of technology to traditional instructional methods. Others compare different software designs or the use of technology under different learning environment conditions. Still others are based on classroom observation.

These studies reflect the broad array of factors that determine the effectiveness of technology-based instruction. Future research is likely to refine our understanding of this complex phenomenon.

Report on the Effectiveness of Microcomputers in Schools: Effects on Student Achievement

Recent original research reports and reviews of educational research strongly suggest that microcomputers and other educational technologies have a beneficial effect on student achievement. For example, in their review and synthesis of recent research, Roblyer, Castine, and King (1988) found research supporting the effectiveness of using microcomputers in instruction in reading, mathematics, science, and problem-solving.

The effectiveness of educational technology, however, depends on a match between the educational goals, learner characteristics, the design of the software, and instructional decisions that affect how technology is used in schools.

In this paper, we report on studies in which microcomputer-based instruction is compared to more traditional methods, and explore recent research that relates student achievement to software design, learner characteristics, and instructional decisions concerning technology implementation.

Comparison Studies

Recent studies comparing technology-based instruction to more traditional approaches have found the technology-based approaches to be more effective. Some noteworthy examples follow.

Problem-solving with databases. A study by White (1987) examined junior and senior high school students' problem-solving skills involving data organization and manipulation. Two instructional treatments were compared: a commercially-available database program (Scholastic's *PFS: Curriculum Data Bases for U.S. History* and *for U.S. Government*) combined with structured printed support materials; and data presented on index cards without structured printed support materials.

Students who used the database program along with the structured materials were found to significantly outperform the other students. It is important to consider not just the use of the computer and software, but the entire "instructional system" -- including the structured print support materials.

Writing to Read. Recent studies (e.g., Ollila, 1987; Whitmer and Miller, 1987) have found that IBM's Writing to Read compares favorably to more traditional early language arts approaches or newer process writing approaches that do not take advantage of computer technology.

Interactive video. In his analysis of evaluations of interactive video, Bosco (1986) included eight studies focusing on the use of interactive video in a school setting. In general, he found that interactive video results in less time required to meet educational objectives and, in many instances, greater student achievement.

A study by Nelson, Watson, and Busch (1989) compared the effectiveness of interactive videodisc to traditional lecture in teaching a science lesson on sea mammals to first graders.

The videodisc software was controlled by Apple Computer's *HyperCard* and allowed children to navigate through a database of visuals, text, and sounds. The lecture treatment included an oral reading by the teacher and a presentation of still pictures, and mirrored the content presented via the interactive videodisc.

Data analysis revealed that the students who used the interactive videodisc significantly outscored the students receiving the traditional lecture approach.

Computer-based encyclopedia. Researchers from Indiana University (Krendl and Fredin, 1985-1986) compared the science term papers of eighth graders using two different encyclopedia systems: a traditional print encyclopedia; and a computer-based videotex encyclopedia system. The computer-based system made it easy to "hop" from topic to related topic, and students could obtain printouts of their searches. The term papers of the students using the computer-based system exhibited significantly greater breadth and depth of knowledge.

Telecommunications networking. Riel (1989) reported on studies designed to assess the effects of electronic networking on students' reading and writing skills. In these studies, a computer-based network linked students in different locations (inside and outside the United States) in reading-writing projects, thus providing an audience of peers and a purpose for students' writing.

One study involved a California fourth grade class in which students used a student newswire service, *Computer Chronicles*, to exchange news stories with students in Alaska, Hawaii, and other parts of California. Each local school developed its own newspaper that included both local stories and stories from other locations. Students in the class that was studied gained, on average, three grade levels in language mechanics and two grade levels in language expression, as measured by a standardized test (the annual Comprehensive Test of Basic Skills). A smaller group of students who volunteered to serve on the editorial board gained, on average, almost four grade levels in language mechanics. The author suggested that experience in editing other students' work played an important role in the achievement gains. She also stressed the role of the teacher in using the computer

and the network to create a new classroom environment -- one more conducive to writing.

Another study, conducted by Cohen and Riel (1989), compared the quality of Israeli seventh graders' writing under two learning conditions: writing for an audience of peers over a network; and writing for an audience of one teacher for the purpose of receiving a grade. The students' compositions written on the network were rated by independent judges to be significantly higher in overall quality than compositions written for the teacher. Compositions written on the network were rated significantly higher for their content, organization, use of language, vocabulary load, and language mechanics.

According to the author, these studies are important because they demonstrate that technology can serve as a vehicle for providing a realistic, meaningful context for student writing.

Other findings. Evidence suggests that microcomputer-based laboratories can be effectively used to enhance students' graphing skills. In addition, writing skills have been shown to improve when the use of a word processor is combined with instruction that provides writing strategies (Capper, 1988).

Achievement, Software Characteristics, and Learner Characteristics

Research suggests that certain software characteristics, such as allowing students to control the kind of feedback they receive (Carrier and Williams, 1988), have a general, beneficial effect on achievement. However, a growing body of research indicates that different learners may experience success with different applications of technology.

The summaries of studies that follow highlight the importance of specific characteristics of both software and learner that contribute to achievement.

Prior knowledge. Gay (1986) provides evidence that learners who have some prior conceptual knowledge of a topic learn best when they have control over the sequence and pace of computer-based instruction, while learners with little prior knowledge may learn best with some program-controlled structure.

The study involved college students taking an introductory biology course. Students worked through a computer-based course, *The Development of Living Things* (WICAT Systems), in either a learner-controlled or computer-controlled version.

The impact of prior knowledge can be seen when we focus on the achievement of students who used the learner-controlled version of the program. Students who used this version and had little prior knowledge of the subject achieved significantly less than

other students. Students who used the same version of the program but who had high prior knowledge were the most efficient learners (taking into account both accuracy and time required). Fortunately, sophisticated computer-managed instructional systems allow teachers to create different versions of the same course -- to meet the needs of different students.

Cognitive style. Research suggests that students with different styles of learning benefit from different kinds of software. One important aspect of learning style is *field dependence*.

Some people can be described as *field dependent*; others as *field independent*. The difference is in how they perceive the world around them (the *field*). Completely field dependent people focus on the totality of whatever they are currently experiencing. They see the forest but not the individual trees. They hear the music but not the individual instruments. Their thinking is dominated by the whole and they have difficulty analyzing the parts. Totally field independent people see the trees that make up the forest. They focus on the instruments, the melody, the harmony, and the rhythm that make up the music. In a word, they are analytical. In the real world, most people fall somewhere between complete field dependence and complete field independence.

Studies by Post (1987) and MacGregor, Shapiro, and Niemiec (1988) involving college students suggest that field dependent learners (non-analyzers) may experience greater academic success with tutorial and practice software, whereas open-ended simulations may benefit field independent learners (analyzers). Technology can be effectively used to accommodate both learning styles.

Preschoolers. A study by Haugland (1989a, unpublished paper) has compared the effects of different types of early childhood software on preschooler's development.

This research is based on a set of guidelines for *Developmentally Appropriate Software for Young Children* (Haugland and Shade, 1988) that include such characteristics as age appropriateness, child control, expanding complexity (low entry; high ceiling), independent exploration (without constant adult supervision), focus on process over product, real-world (concrete) representation, and visible transformations (of objects and situations). Using these guidelines, some early childhood software programs can be characterized as developmental (e.g., an open-ended microworld in which children can interact with real-world characters, objects, and scenes); some programs are not developmental (e.g., a drill program involving abstract objects and no real-world context).

In Haugland's study, children exposed to developmental software showed significant gains in general intelligence, and cognitive and motor development. For children who used non-developmental

software, significant gains were demonstrated for concentration and short-term memory.

Learning disabled students. A number of researchers have explored the special requirements of disabled learners when it comes to technology applications. In his recent literature review, Hasselbring (1990, unpublished paper) found that computer-based drill and tutorial software for the learning disabled must reflect precisely the skill that is targeted for improvement. In addition:

* Math facts drill and practice software leads to fluency for facts that learners can already recall from memory.

* A different software design can be employed to achieve fluency for new facts -- training in recalling math facts from memory, combined with drill and practice. This computer-based approach is more effective than traditional instructional methods.

* Carefully designed software that practices word analysis skills is effective in increasing the fluency of word decoding skills.

* Computer-based spelling programs that use a voice to present the target words are superior to traditional methods that include a visual presentation of the word. The voiced presentation requires retrieval from long-term memory, whereas visual presentation only requires retrieval from short-term memory.

Other research (Keene and Davey, 1987; Casteel, 1988-1989) suggests that appropriately-designed software helps improve learning disabled students' reading comprehension strategies. In addition, a simulation has been used to help such students improve their problem solving skills (Woodward, Carnine, and Gersten, 1988).

Johnson, Gersten, and Carnine (1987) compared the effectiveness of two versions of a vocabulary development software program intended for high school LD students. Students using a version of the program providing fewer exercises per set showed significantly greater achievement gains compared to students using a version with more exercises per set. One of the computer's strengths is that the size of the practice set can easily be tailored to meet individual student's needs.

Researchers at the University of Nebraska's Educational Center for Disabled Students (Shell, Horn, and Severs, 1988) studied the impact of implementing computer-based services for disabled college students, including modifications to computer hardware to provide students with computer access, and application of

microcomputers and other technologies to help students overcome their sensory and motor limitations (e.g., providing lap-top computers for notetaking in class). Students were also given training in hardware and software operation, as well as in academic skills (typing, writing, language comprehension, and study skills). Students receiving these services had significantly fewer occurrences of academic suspension and probation than disabled students who did not receive the services. Furthermore, the level of academic suspension and probation for disabled students receiving the computer-based services was equivalent to that of the general student population. The degree to which disabled students took advantage of these services was found to be a significant predictor of their semester grade point average.

Achievement and Technology Implementation Decisions

Research suggests that the way in which teachers and schools organize a technology-based learning environment affects student learning. Structuring the classroom so that the computer becomes a center for both intellectual pursuit and social interaction enhances students' learning experiences.

The microcomputer can be a catalyst for small group and cooperative learning, providing opportunities often missed in traditional classrooms. Research suggests that small group, cooperative learning on the computer results in greater achievement gains and faster rates of learning (Johnson, Johnson, and Stanne, 1986; Carnes, Lindbeck, and Griffin, 1987; Dalton, Hannafin, and Hooper, 1988).

In a preschool environment, students will benefit when the computer is made an important hub of learning activity. Research conducted by Haugland (1989b) indicates that placing computers in a central location in the preschool results in greater developmental gains than placing the computers in relative isolation.

In Conclusion

The time has come to stop asking the question, *Which are better, technology-based instructional approaches or traditional ones?*

It is easy to conceive of conditions under which a technology-based approach is superior (e.g., the teacher cannot give a student the individual attention needed; new technology is developed that provides opportunities never before available, such as multimedia).

One can also conceive of conditions under which a traditional approach is superior (e.g., there is a mismatch between the

available software and the learner; the traditional approach provides an experience that technology cannot, such as a field trip requiring the use of all five senses).

More often than not, technology can be used to support traditional approaches and to provide alternative methods.

The time is ripe to focus on more important questions -- concerning the best mix of technological capabilities, and the conditions under which these capabilities can be used effectively with various student populations and in different learning environments to meet a wide variety of educational goals. The research we have reported in this section begins to address these questions.

Report on the Effectiveness of Microcomputers in Schools: Effects on Student Motivation and Attitudes

Recent research demonstrates the power of microcomputers and other educational technologies to motivate students and to improve their attitudes about learning and themselves.

Students Like Using Computers

Students enjoy using computers (Forsyth, 1986; Apostolides, 1987). In fact, recent studies indicate that many students perceive computer-based instruction to be more motivating than traditional methods (Hauben and Lehman, 1988; Krendl and Lieberman, 1988; Watkins, 1989).

This positive feeling towards computers is found across the entire grade range -- from preschool through college. It is a feeling common to male and female students.

This favorable reaction to computers is shared by both mainstream and learning disabled students. In a study by Lieber and Semmel (1987), 89 percent of mainstream students and the same percentage of learning disabled students indicated that they like working at the computer. Students in both groups who did not like working at the computer explained that the task was too difficult. Other studies support the attraction that learning disabled students have for computers (Harper and Ewing, 1986; Keene and Davey, 1987; Watkins, 1989).

Evidence suggests that students' positive attitude toward computers is based on actual experience. In fact, their attitude about computers seems to improve after using them (Justen III, Adams II, and Waldrop, 1988; D'Souza, 1988).

Why Students Like Using Computers

Research suggests several software design characteristics that make computers motivating to students.

Students enjoy being actively engaged and being able to make mistakes without embarrassment (Apostolides, 1987). They prefer the availability of immediate, helpful feedback (Seymour, Story, and Mosley, 1986; Hauben and Lehman, 1988). They are motivated by graphics and game formats (Rowe, 1986, unpublished paper). Borgh and Patrick (1986) found that most elementary schools students preferred using a word processor when it was equipped with a speech synthesizer; less skilled writers were the ones most motivated by the synthesizer.

Learner control. Several studies have suggested that computers are motivating because they give students the feeling of being in control. For example, Shade, Nida, Lipinski, and Watson (1986) found this to be the case for preschoolers. After gaining experience with some of the programs in the *Stickybear* series (Weekly Reader Software), children were able to manipulate the keys to see a particular graphic, change disks, follow simple directions from a picture menu, and anticipate what would happen next on the screen. They enjoyed showing off these abilities to others.

A study by Kinzie and Sullivan (1989) compared the motivational effect of computer-based instruction under two different conditions involving control of feedback: learner control of review sequences following an incorrect response; and automatic presentation of these sequences. Eighty percent of all the students indicated a preference for the version of the program that gave them control over the review sequences.

Fortunately, when computer programs afford students control over aspects of the learning environment, the software can be designed to encourage students to make educationally sound choices. Carrier, Davidson, Williams, and Kalweit (1986) examined the effect of encouragement statements on students' use of a computer program that offered various forms of optional feedback (e.g., paraphrased definitions; additional examples of concepts; analysis of errors). Two versions of the program were used. In one version, students were encouraged to select among these feedback options; the other version did not include such encouragement. Students who received encouragement selected more feedback options than those who received no encouragement.

Motivating Students to Remain On-task

Several recent studies indicate the power of the computer to keep students on task -- an important contributing factor to student achievement.

Capper (1988) identified studies exploring uses of database software, word processing software, simulations, and microcomputer-based laboratories, in which students were found to persist at tasks that require higher order thinking skills.

Stein (1986-1987) observed student behavior in a microcomputer-based laboratory, using a specially-tailored curriculum for the physical sciences. Off-task behavior was less than two percent of the total laboratory time.

In a study of computer-using kindergarten students, Bergin, Ford, and Mayer-Gaub (1986) found that the children were on task approximately 90 percent of the time when working in pairs with a variety of age-appropriate software over a period of four months.

Studies have documented high levels of on-task behavior for both learning handicapped and mainstream students using the computer in subject areas such as mathematics, writing, typing, and Logo programming (Semmel and Lieber, 1986; Cosden and Semmel, 1987).

Affecting Students' Attitudes Towards School

Recent review articles and original research indicate that computer use positively effects students' attitudes toward school learning, in general, and toward specific school subjects, including writing, reading, mathematics, science, and business (Rieth, Bahr, Polsgrove, Okolo, and Eckert, 1987; Chamberlin, 1988; Krendl and Lieberman, 1988; MacGregor, Shapiro, and Niemiec, 1988; Roblyer, Castine, and King, 1988; LaBonty, 1989). Bosco (1986) found that the use of interactive video has also resulted in positive student attitudes.

Reducing "math anxiety". Rowe (1986, unpublished paper) studied the effects of a computer game on the performance and attitudes of bright female algebra students who described themselves as "math anxious."

The computer game, *Algebra Arcade* (Brooks/Cole Publishing Company), involves graphing equations to knock down on-screen creatures called *Algebroids*. Graphs are created by writing algebraic expressions. There is also a practice workspace, where students can practice creating graphs away from the game.

While using the software and later while trying to apply the concepts learned to science problems involving graphs, the students' behavior indicated that their "math anxiety" had lessened. They also demonstrated the ability to apply what they had learned to new situations.

Continuing motivation. Evidence suggests that computer-aided instruction can sometimes stimulate continuing interest in a subject area or content topic.

Seymour, Story, and Mosley (1986) compared the effects of computer-based and print-based instruction on their ability to motivate upper elementary students over time. The topic was energy sources. Significantly more students who worked on the computer indicated a preference for continuing the study of energy sources, rather than switching topics or not studying any topic. Malouf (1987-1988) found that after using a drill and practice game on prefixes, learning disabled students showed an increased tendency to select a similar off-computer task when offered a choice of activities. The importance of these studies is the continued motivational effect of computer-based instruction -- an effect that apparently carried over to off-computer learning activities.

Affecting Students' Self-Esteem

Two recent reviews of research provide evidence that microcomputers are effective in improving students' self esteem (Roblyer, Castine, and King, 1988; Chamberlin, 1988).

Robertson, Ladewig, Strickland, and Boschung (1987) compared two versions of a high school home economics course. One used the computer for supplementary work; the other did not. Students who completed the course with the computer-based instruction scored significantly higher on a measure of self-esteem than students who completed the course without using the computer.

Empowerment. Related to self-esteem is a feeling of *empowerment* -- a state in which students see themselves as responsible for and in control of their own learning. Fisher (1989) found that learning conditions linked to empowerment are often prevalent in classrooms with high access to computers.

Researchers at the University of Maryland (Wright and Samaras, 1986) observed preschoolers over a four month period following the introduction of two microcomputers, available during free play time. The children often experienced and expressed a sense of mastery over machine -- a sense that they were able to control their environment. The authors linked these feelings to the development of a positive self-image.

Self-efficacy. Also related to self esteem is *self-efficacy* -- an individual's personal judgement about his or her ability to perform in a specific situation (Schunk, 1985). In a pilot study, Graham and MacArthur (1988) found that learning disabled students' self-efficacy concerning writing increased after learning a self-instructional, multi-step strategy for revising their own essays using a word processor. This increase mirrored actual improvements in writing quality, as assessed by independent judges.

In Conclusion

The evidence in support of using microcomputers and related technologies to motivate students and to improve their attitudes is plentiful and, in some instances, quite dramatic. Schools across our nation are just beginning to tap this potential.

It is important to remember, however, that the use of educational technology does not occur in a vacuum. Schools must provide an instructionally sound, caring learning environment. Creating such an environment depends on well-trained teachers.

Report on the Effectiveness of Microcomputers in Schools: Effects on Social Interaction in the Learning Environment

Recent research indicates that the use of microcomputers and other educational technologies can have important, positive effects on social interactions among teachers and students. These interactions sometimes result in greater student achievement.

How Students Relate to One Another

While educational technology can be used to provide effective, individualized instruction, this does not mean that computer-based learning has to be an isolating experience. In a survey of high school reading teachers (Hague, Childres, and Olejnik, 1986), 75 percent disagreed with a statement that computers isolate students from each other. In fact, research indicates that educational technology encourages cooperative learning among students (e.g., Krendl and Lieberman, 1988). Cooperative learning on the computer has also been linked to increased content-related student talk (Johnson, Johnson, and Stanne, 1986; Fish and Feldman, 1987).

Technology-based writing. A recent report from the Apple Classrooms of Tomorrow project on student writing in a computer-intensive learning environment (Hiebart, Quellmalz, and Vogel, 1989) found that there was greater sharing of written work among students. Researchers attributed this increase to the computer's ability to generate legible text on screen and in printouts.

Newman (1990) observed that after working collaboratively on a local area network, many students spontaneously used the network to write to other students, on a personal basis.

Riel (1989) cites examples of students using telecommunications software to share their writing with students in other countries and various states within the U.S. in carefully organized reading-writing projects. The author found that the network and the projects provided a meaningful audience of peers and a purpose for students' writing. As a result, students demonstrated dramatic gains in reading and writing.

Using databases. In her recent review of educational technology research, Capper (1988) cited informal observational studies reporting student cooperation when working in groups with database software. Newman (1990) reported similar findings when students used a centralized database on a local area network.

Learning disabled students. Lieber and Semmel (1987) studied the changing attitudes of learning disabled students after working on the computer individually and in pairs. After four weeks at the

computer, there was a significant shift among these students in favor of working with a partner.

Young children. Observations of preschoolers and kindergarteners have revealed that using the computer is frequently a cooperative, social experience for young children (Bergin, Ford, and Mayer-Gaub, 1986; Shade, Nida, Lipinski, and Watson, 1986; Wright and Samaras, 1986). Turn-taking, verbal sharing of skills, and peer tutoring are typical behaviors.

Researchers at the Child Development Center of De Anza College, in Cupertino, California (Muhlstein and Croft, 1986), studied the social and cooperative play behavior of preschoolers at the computer when teachers were provided with guidelines for maximizing such behavior. In comparison with off-computer activities, computer-based activities were the only ones that resulted in high levels of both language development and cooperative play simultaneously.

Haugland (1989b) found that placing computers in a central location in a preschool stimulated discussion among students as to what they were doing -- including children who were at the computer and those engaged in other activities. The computer became the heart of classroom activity and social interaction.

How Teachers Structure the Learning Environment

Research is beginning to emerge showing that technology can affect the way teachers structure the learning environment and their own role within that environment.

Earth Lab. Earth Lab is an experimental instructional system that includes a computer-based local area network, a science curriculum designed for use on the network, and software tool programs. Newman (1990) reported on important changes in an elementary school learning environment after introducing Earth Lab.

The science curriculum included activities that stressed student-to-student communication and collaboration. The software tools provided word processing, electronic mail communication, and a centralized, shared database. The software provided for both individual and group "workspaces" for saving students' written work.

The network enabled teachers to organize science projects so that different student groups contributed different data to a larger inquiry, using the centralized database. The relationship between this larger set of data and the contributions of individual groups became the focus of large group discussions. This activity structure -- having student groups be contributors to a larger inquiry -- more closely resembles the work of

professional scientists, and had never been experienced in the school before the introduction of the network.

Over the course of the initial year, classroom teachers gradually increased the number of small group learning experiences, including activities that were not included in the original science curriculum materials.

The network provided channels of communication that had not existed before. Students and teachers carried on individual, written conversations -- conversations not necessarily related to planned activities. There was also evidence of increased collaboration among teachers. For example, classroom teachers developed small group lessons in subjects other than science, using the small group organization developed by the science teacher.

Structuring classrooms for student empowerment. An Apple Classrooms of Tomorrow project (Fisher, 1989) focused on classroom conditions that have been identified as contributing to a feeling of student *empowerment* -- a state in which students see themselves as responsible for and in control of their own learning. The study compared the learning environment of a classroom with high access to computers to that of a classroom with low computer access.

Conditions linked to empowerment that were more prevalent in the high computer access classroom included: student input in shaping the learning task; private and task-related evaluative feedback to students; assignments that take longer to complete; and tasks requiring problem solving and other higher-order cognitive behaviors.

Rhoads (1986) found that students engaged in microcomputer-based instruction with a partner required less teacher assistance than did subjects working alone.

Shade and Watson (1987) have offered evidence that the interaction between adults and children when using a computer is dependent on the type of software. They compared the interaction patterns of mothers and their preschool children when working with two different types of software: an open-ended microworld in which children can experiment with the concepts *inside/outside*; and an alphabet drill program.

Results indicated that interaction patterns were different for the two types of software. Mothers working with the microworld gradually gave their children significantly more control over the software. These mothers also increased their amount of verbal instruction, and decreased the amount of pointing and demonstrating how the software worked. Mothers working with the drill software showed no significant changes in how they interacted with their children. It is likely that the type of

software will influence the teacher's role, much as it did the parent's role in this study.

In Conclusion

The potential of technology to stimulate important changes in the school learning environment is real -- and should be exploited.

It is clear, however, that technology cannot affect the ways in which students and teachers interact by itself. Also needed are teachers who are skilled at structuring effective learning environments and who are flexible in the roles they will play -- sometimes lecturer, sometimes tutor, sometimes poser of thought-provoking questions, sometimes project manager, sometimes diagnostician.

A partnership among schools, teacher training institutions, the research community, and the educational technology industry is essential.

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